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AN INVESTIGATION OF SYSTOLIC-DIASTOLIC BLOOD PRESSURE DIFFERENTIAL AS A MEASURE OF HUMAN ENERGY EXPENDITURE

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SUMMARY

The differential between the systolic and diastolic blood pressure levels was investigated as a measure of human energy expenditure. During the investigation, fifteen male subjects performed nine different tasks on a bicycle ergometer. The tasks were combinations of three different horsepower outputs per minute: .03, .05, and .07 horsepower and three different time durations: two minutes, five minutes, and eight minutes. The subjects' blood pressure was measured immediately before and immediately after the performance of each task with a sphygmomanometer.

Three pressure variables were considered: post-task pressure level, difference between post and pre-task pressure levels, and per cent increase of post over pre-task pressure level. Analysis indicated that the level of the variables changed as the duration of the task or the energy output per minute of the task changed, but that the change was not always significant and was not homogeneous for the different subjects. The lack of homogeneity between subjects could not be accounted for by differences in the environmental conditions in which the subjects performed or by differences in physical fitness as measured by a military physical fitness test. Analysis further revealed that the variables were not indicative of the energy expended when the subjects were considered individually. Consequently, it was concluded that when tasks of a pedaling nature are performed by a human operator

measurement of the differential between the systolic and diastolic blood pressure levels of the operator is not a reliable indicator of the energy expended in performing the tasks.

CHAPTER I

INTRODUCTION

This study is an investigation of one possible measure of human energy expenditure occurring during the performance of muscular work. The measure is the differential between the systolic and diastolic blood pressure levels. Few operationally useable measuring techniques are available to the individual interested in measuring the energy expenditure occurring during the performance of work, and this investigation was conducted to determine if the measurement of systolic-diastolic blood pressure differential could become a relatively reliable measuring technique.

Several professional groups including biologists, engineers, physiologists, psychologists, and sociologists are interested in man's relation to his working environment and in improving work systems. Of these groups, industrial engineers have been most concerned with the actual design of motion patterns to be followed in performing tasks, and work measurement techniques such as stop watch time study and predetermined time systems, for example, have been developed to aid them in measuring the work content of tasks. These rules and techniques are operational and have been used with some success in industrial practice for a number of years. Present task design and work measurement techniques could perhaps become more reliable, however, if they more adequately considered the ability of the human body to produce mechanical energy and the physiological cost of such energy production (1).

Experiments have been performed to study the physiological effects of muscular work and have shown that several physiological functions change from a resting level to a working level as an individual performs a task. For example; heart rate, blood pressure, cardiac output, pulmonary ventilation, oxygen consumption, chemical composition of the blood and urine, body temperature, and the chemical state of muscles are all changed by muscular activity (2) (3). Some experimenters, Brouha for example (4) (5) (6), have shown that certain of these physiological variables can be used to indicate the amount of energy expended in the performance of a task; however, most of the measuring techniques used to obtain the data can not be considered appropriate except in the laboratory. Two investigations (7) (8) have suggested the possibility of using the differential between the systolic and diastolic blood pressure levels as a measure of human energy expenditure, and the present experiment is designed to investigate the capability of this measure to indicate the amount of energy expended.

The following summary of the phenomenon of blood pressure will describe the variable under consideration. Blood, like any other fluid, exerts force against the wall of the vessel in which it is contained, and it is this force to which one refers when speaking of blood pressure. As a consequence of the construction of the circulatory mechanism of the body, the pressure in the arteries is more directly influenced by the cardiac cycle than the pressure in the veins. For this reason, and since arterial pressure is much greater and easier to measure than venous pressure, the arterial pressure is usually measured when one is interested in obtaining a blood pressure measurement. As a result, the term "blood pressure" has come to connote arterial pressure and is so used in this thesis.

In the cardiac cycle venous blood from the body enters the right atrium, passes into the right ventricle, is pumped to and circulates through the lungs, returns to the left atrium, enters the left ventricle, and is pumped into the aorta and thus throughout the body through the smaller arteries (9 p. 260). The cycle consists of two phases: a contraction, or systole, phase and a relaxation, or diastole, phase. The pressure occurring in the arteries resulting from the contraction phase is termed systolic pressure and that resulting from the relaxation phase the diastolic pressure. The difference between these two pressures is termed the pulse pressure (10 p. 497) and is the variable of primary interest in this thesis.

In the present investigation the pulse pressure of fifteen male subjects ranging in age from twenty-one to fifty-one will be measured before and after they have performed work of varying intensity and duration on a bicycle ergometer. If the data from the experiment indicate that there is no significant difference, or at least no difference that can not be predicted and taken into account, between the pulse pressure levels of different individuals after they have performed work of the same intensity and duration, but that a significant difference does exist when work of different intensities and durations is performed and this difference is consistent for all individuals, then it could be concluded that pulse pressure might be used as a measure of the energy expended in performing work.

CHAPTER II

LITERATURE SURVEY

An initial cursory examination of work measurement literature revealed that several variables have been investigated as possible indicators of the energy expended during the performance of work by humans. Two of these variables, oxygen consumption and heart rate, appeared to have been studied in some detail; whereas others had received less attention. Of those that had received only exploratory investigation, the difference between systolic and diastolic blood pressure levels appeared to be most promising as a good indicator of energy expenditure. Consequently, a search of both the physiological and work measurement literature was undertaken to familiarize the author with previous experimentation utilizing some measure of blood pressure as a work measurement device and also with the factors that affect blood pressure levels. In addition, a survey was made of literature concerning the variables of oxygen consumption, heart rate, heart sound, galvanic skin response, and reaction forces. Results of the survey, along with a discussion of blood pressure, are presented in this chapter.

Oxygen Consumption

The quantity of oxygen consumed by the body during the performance of work has been investigated as a measure of energy expenditure. In some of the early experimentation researchers attempted to obtain reliable information concerning energy expenditure by measuring the amount of oxygen converted to carbon dioxide during the performance of a task (11). Although the equipment was cumbersome to the worker and the data were somewhat tedious to analyze, this method provided some useful information concerning the energy efficiency of such jobs as pushing wheelbarrows and filing metal. The reader may refer to Barnes (12) for a summary of the conclusions reached in a portion of this early experimentation.

A study of oxygen consumption as a function of the number of foot-pounds of work performed led Schneider to the following conclusion: "... with moderate loads of work the adding of equal increments to the load results in approximately equal increments in the absorption of oxygen" (13 p. 355). Studies of walking have shown, furthermore, that minimal oxygen cost resulted when individuals walked at or near the supposedly "normal" pace of three miles per hour (12) and Lauru (1) has found that minimal oxygen consumption results when tasks are performed using motion patterns judged to be superior by force platform analysis as opposed to using other patterns. Oxygen consumption thus appears to be related to the amount of work performed.

Anson (14) undertook an experiment to determine if the oxygen cost per minute to the worker could be used as a measure of the characteristic which time study analysts assess while making time study ratings. Anson's results led him to conclude that oxygen cost per minute is not the characteristic assessed by time study analysts or even a measure of the characteristic.

The use of oxygen consumption as a measure of energy expenditure has proven successful, using methods developed at the Max-Planck-Institut Für Arbeitsphysiologie in Dortmund, Germany. The Max-Planck method is actually an indirect calorimetry method measuring energy expenditure in terms of caloric values. The caloric values depend upon the oxidation of nutritive materials such as fats, carbohydrates, and proteins, however, and oxygen consumption thus can be used to measure the energy expended. Laboratory experiments as well as measurements of the energy expenditure of certain agricultural tasks have been successfully performed in this country using the Max-Planck method (15).

In a review of experiments utilizing indirect calorimetry covering the period 1900 to 1955, Passmore and Durnin (16) state that the validity of indirect calorimetry as a basis for measuring energy expenditure has been firmly established. Their review includes experiments concerned with the energy expended during sleep, industrial work, and recreational activities and also the effects of age, sex, body size, race, and climate upon energy expenditure. Included in their review is a suggested physiological basis for grading industrial work (p. 832).

Although oxygen consumption may be a good indicator of energy expenditure, it has not been shown to be a good measure of overall physiological costs. Brouha and Maxfield (6) have reported experiments demonstrating that oxygen consumption during work and the rate at which it returns to a resting level are affected only to a minor degree by environmental conditions, and that it does not indicate the increase in physiological strain which is known to occur when work is performed in uncomfortable surroundings.

In summary, the rate of oxygen consumption during the performance of a task can be used to indicate the amount of energy expended, particularly when used in indirect calorimetry; however, it does not seem to be a good indicator of overall physiological costs.

Heart Rate

The possibility of using the human heart rate as an indicator of the physiological costs of work has received considerable attention from Brouha (2) (4) (6). Brouha's experiments include the effects on heart rate of work, exercise, temperature, impervious clothing, age of subject, time of day, and adequacy of water supply. His method consists of counting the pulse rate at one minute intervals during the first three minutes of the recovery period following the termination of work while the subject is sitting quietly. The pulse rates are used to construct "heart rate recovery curves" which indicate the actual value of the pulse and the rate of recovery toward the resting level (4). Brouha's experiments indicate that pulse rate changes give satisfactory measurements of the physiological expenditure that is required of a given job provided the job is of a relatively strenuous nature; the heavier the physiological load the higher the heart rate and the more slowly the return to normal. Brouha has further shown that heart rate responses indicate not only the increased strain of performing an individual work period, but also the rapid accumulation of strain induced with each successive cycle (6). From his experiments he has concluded that if the average value of the final recovery pulse is maintained at about 110 beats per minute, the work can be maintained in a physiological steady state. The physical condition of the worker has some effect on the heart rate, however, for the better his condition the smaller will be the increase in heart rate for a standard work load and the more rapid the return to a resting level.

Several investigators have reported results tending to support the conclusions drawn by Brouha. Asmussen and Nielsen (17) have reviewed several experiments and concluded that as the individual changes from a resting to a working condition the pulse rate immediately increases very rapidly and then continues to rise at a more gradual rate toward a steady state condition. Experimentation at the Max-Planck-Institut (18) has shown that a rising pulse level over the working day is a significant indicator of increasing fatigue and that heart rate is correlated with caloric output. Hall (7) found that heart rate increased significantly as time on a cycling task progressed, and Suggs and Splinter (19) found that the relation between heart rate response and workload increased linearly. Schneider cautions, however, that "It is also evident that eventually a load of work may be undertaken to which the heart is unable to respond with any further increase in frequency of beating" (13 p. 357). Furthermore, Edholm, et al. (20) have shown that heart rate may be significantly affected by the degree of acclimatization of the worker who is performing in extreme temperatures and present a correction factor which must be applied to the heart rate data if reliable determinations of energy expenditure are to be made in abnormal temperature conditions.

Deney (21) has shown that heart rate measured immediately after the completion of a task correlates highly with work pace, and Young (22) has investigated the possibility of using heart rate as an objective method for rating operator performance on jobs of varying physical difficulty.

Young's results showed that the combined effects of task difficulty and operator pace, which he termed work intensity, could be predicted from heart rates measured after the performance of work; however, a slight significant difference was found to exist between rates of individuals performing the tasks.

In summary, heart rate appears to be a good indicator of the physiological costs incurred in performing work although it is somewhat limited by the manner in which it is affected by the physical fitness of the individual. It is interesting to note that several of the "principles of motion economy" (12 p. 214) have been evaluated using heart rate as a criterion and have been substantiated as valid principles (23).

Heart Sound

Schwartz (8) has conducted what appears to be the only investigation of heart sound as an indicator of the physiological costs of work. His results showed that heart sound intensity increases linearly as work periods progress, and he concluded that it probably is an accurate indicator of fatigue in jobs of a light nature. Nevertheless, he pointed out that heart sound intensity could not be considered an operational measure using the then available equipment due to error introduced in the sound recordings by the subject's physical activities of speaking and coughing and by extraneous environmental noises.

Galvanic Skin Response

Galvanic skin response, a measure of the electrical resistance of the skin, has also been investigated as a measure of physiological costs. Ekey and Hall (24) state that the level of skin resistance is often regarded as being dependent upon the general level of excitation of the muscles of the body; however,

> "There is still much fundamental research to be done in determining exactly what it measures, how much influence relatively unimportant factors may have upon the level of resistance, and how accurate it is as a measure of the amount of effort being expended as well as a reflection of the relative changes of effort" (p. 250).

Blank and Finesinger (25) found that the galvanic skin response increased immediately in a step test, and Hall (7) found that it increased linearly with work over time. Hall also found the galvanic skin response to be nonhomogeneous among individuals, thus casting some doubt on its use for work measurement.

Force Platforms

In an effort to determine physiological costs without actually measuring a physiological variable and thus avoiding the necessity of having to burden the worker with recording devices that might interfere with his normal tasks, several investigators (1) (26) (27) (28) (29) have become interested in designing and utilizing platforms that will measure the reaction forces produced by workers while performing tasks. The force platform, as initially developed by Lauru (1), consists of a triangular platform mounted on quartz crystals that can sense the verticle, horizontal, and transverse forces developed by a worker performing tasks while standing on the platform.

Although the force platform measures forces only and not a physiological variable, the platform data can be manipulated so as to give a reliable indication of the physiological costs of the work and thus may be quite useful as a measuring device (29). In addition to its possible use in work measurement, the force platform may be useful in methods analysis and task design. Lauru (1) has used the platform to select the motion pattern requiring the least amount of physiological costs from among all possible patterns that could accomplish the same task, and Hudson (27) has found the use of a force platform helpful in determining the correct dimensional characteristics of workplaces.

Blood Pressure

The possibility of utilizing some measure of blood pressure as an indicator of the energy expended during the performance of work can be comprehended more fully if one is aware of some of the factors affecting blood pressure levels. Consequently, a discussion of factors affecting blood pressure is presented before proceeding to a discussion of experimentation investigating this variable.

Several investigators have reported that blood pressure levels can be affected by social, environmental, psychological, and physical factors. Of these four, social factors seem to have the least effect, and evidence concerning them is somewhat sparse. Some of the social factors reportedly having an effect on pressure are type of occupation, marital status, size of family and social status (30).

Certain environmental factors definitely have an effect on blood pressure. Stroud, (31) in a survey of a number of articles, reported that a warm environment will result in lower pressure levels than a cool one and that barometric pressure has no significant effect. Stroud further stated that there is a dinural increase in pressure. Another writer, Comstock (32), agrees that temperature has an effect but questions the conclusion that dinural increases in pressure occur.

Almost all experimenters agree that the pressure level can be affected by psychological factors. Stroud (31) presents a comprehensive discussion of these pointing out that feelings of pleasure, anger, fright, apprehension, excitement, and general nervousness may raise pressure; whereas blood pressure may fall during feelings of compliance and submission. Stroud further states that the pressure is normally somewhat elevated when it is read for the first time, but that an explanation of the procedure being followed will generally eliminate all or most of this effect.

The most significant factors affecting blood pressure are physical in nature. Pressures have been found to correlate positively with weight and age, and tables giving average pressure levels in relation to weight and age have been constructed (33) (34). Furthermore, a significant variation in pressure has been reported to exist between the sexes and among the races (31) (32) (33). This study is particularly concerned with the physical factor of exercise, and some findings concerning its specific effect should be mentioned.

As soon as exercise begins the contracting muscles produce carbon dioxide and other muscle metabolism products which cause the blood vessels to dilate and thus increase the flow of blood to the active tissue. This increased flow of blood to the active area triggers certain physiological mechanisms which cause an increase in heart rate and stroke volume and, consequently, an increase in blood pressure (9 p. 352) (17). Systolic pressure normally demonstrates a greater per cent rise than does diastolic with the result that the difference between the two, pulse pressure, increases. Both pressures tend to rise more during rapid and exhaustive exercise than during exercise of a moderate nature causing a corresponding increase in pulse pressure. It is interesting to note that the performance of static exercise, such as the squeezing of a dynanometer, causes pressure to rise to a different level than that resulting from the performance of an equal amount of dynamic work (35) (36).

Following the performance of exercise, systolic, diastolic, and pulse pressures all fall to subnormal levels; the level to which pulse pressure falls being relatively equal regardless of the intensity of the exercise performed. Pulse pressure returns to normal more slowly the more exhaustive the exercise, however (37).

Although it has been concluded that measurement of blood pressure levels can not be used to predict the capacity of individuals to perform work (5), experimentation seems to indicate that some measure of blood pressure might be useful in work measurement. Burger, et al. (36) found that the reaction of systolic pressure to both cycling and cranking tasks followed the same pattern as did the heart rate response to these tasks. Furthermore, Hall and Schwartz (7) (8) have reported that pulse pressure seems to have possibilities as a work measurement tool.

While measuring certain physiological variables of subjects performing non-strenuous work on a torsion bar device, Schwartz (8) found that "... both systolic and diastolic blood pressure varied significantly among workers. . . however, the difference between systolic and diastolic pressures was not significantly affected by the various operators" (p. 25). Hall (7) found only slight variation in pulse pressure between subjects who were performing work of a strenuous nature on a bicycle ergometer, thus showing that the condition of homogeneity held for both mild and strenuous exercise and ruling out the possibility that the lack of significance was due to low energy output. Hall and Schwartz both found that pulse pressure showed a quadratic relationship with time as the work period progressed, that pulse pressure increased significantly as the time at the task increased, and that it showed a significant variation due to speed when work of constant load was performed. Hall further noted that pulse pressure discriminated among loads as the heart rate approached a maximum. Both authors stated that although their results were encouraging, experiments should be undertaken to validate them using longer time periods and work loads of varying intensities. The present experiment is designed to serve a part of this validation procedure.

Summary

The present literature survey indicates that measurements of oxygen consumption and heart rate have been successfully utilized to indicate the energy expended during the performance of work. Of the other variables considered, pulse pressure measurement appears to hold the most promise as an additional measure of energy expenditure, and it is the purpose of the present investigation to provide information concerning the capability of this measure.

CHAPTER III

INSTRUMENTATION

The major pieces of equipment used in this experiment were (1) a Riester aneroid sphygmomanometer, (2) an Arhoo stethoscope, and (3) a friction-brake bicycle ergometer. Other equipment included a Minerva decimal-minute stop watch for timing the length of tasks and an Air-guide combination barometer for measuring the temperature, relative humidity, and barometric pressure in the laboratory. A discussion of the selection of the sphygmomanometer as a measuring device and a functional description of the bicycle ergometer follow.

Sphygmomanometer Selection

At present there are two techniques generally employed for obtaining arterial blood pressure measurements. One of these, intra-arterial catheterization, gives a direct reading of the pressure as the blood is able to work directly against a manometer; however this method requires surgical procedures that are not feasible when experimenting with human subjects (38). The second method, sphygmomanometry, results in indirect measurements of intermittent systolic and diastolic pressure levels. Although it has been argued by some that sphygmomanometers are incapable of accurate or reliable measurements (39) (40), an experiment in 1960 (41) indicated that sphygmomanometry, if practiced carefully, is reliable even though it seems to systematically underestimate the systolic and overestimate the diastolic pressure.

Other methods of measuring blood pressure have been attempted, "... including the measurement of arterial distension, of pulse wave velocity, and of opthalmic artery occlusion, and the use of finger type sphygmomanometers" (p. 1, (42)). None of these methods has proven to be particularly successful, however, and even those that seem to be somewhat promising have not been thoroughly tested (42) (43) (44).

In view of the fact that intra-arterial catheterization is infeasible, that no new measuring devices have been perfected, and that sphygmomanometry has been shown to be reliable, the sphygmomanometer was chosen as the device to be used to measure blood pressure levels in this experiment. In an effort to reduce possible measurement error, the American Heart Association's recommendations for determining human blood pressure by sphygmomanometers were followed (40).

Friction-Brake Bicycle Ergometer

The task device used in this experiment was a bicycle ergometer provided with a calibrated spring brake for varying the work load and an electrically driven tachometer by which the subject could regulate his speed. Structural features of the device include adjustments for seat height, length of reach to the hand grips, radius of pedal arc, and elastic pedal straps for securing the pedaler's shoes to the pedals. Figure 1 presents a photograph of the bicycle ergometer.

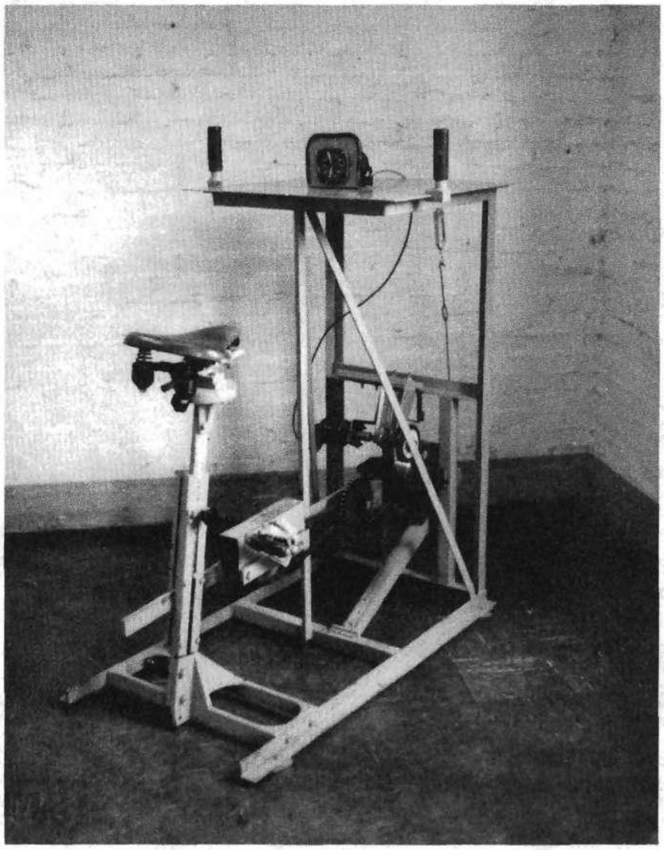

Figure 1. Friction Brake Bicycle Ergometer.

(Photograph courtesy Mr. R. M. Thompson, Jr.)

CHAPTER IV

EXPERIMENTAL PROCEDURE

Descriptions of the laboratory, the experimental subjects, the tasks, the experimental design, the concomitant variables considered, and the procedure followed are presented in this chapter.

Laboratory

The experiment was conducted from April 29 to May 22, 1963, in a basement room of the School of Industrial Engineering of the Georgia Institute of Technology. The room had previously been used as an office by a member of the Industrial Engineering staff. The room was 9.75 feet long by 9.4 feet wide, had a brown tile floor with a border of black tile and was lighted by two fluorescent lighting fixtures which hung from the ceiling. The light intensity within the room was twenty foot-candles which is within the recommended range for industrial work places (45). The walls of the room were of brick painted a light pea-green with an eight inch border of darker green at the bottom. The ceiling was made of white plaster board. The room was ventilated by a center-hung transom window which was kept open during the experiment but was covered by a curtain to provide privacy. In addition to the bicycle ergometer, the room contained a swivel chair with a padded seat, a writing table, a stool, a hat rack, a tape recorder, the Air-Guide combination barometer, a trash can, a time study clip board, and miscellaneous hand tools used to adjust the bicycle pedals. The tape recorder and the barometer were positioned on the writing table along with the clip board which contained the data sheets and held a stop watch used for timing the work periods. The Appendix contains a sample data sheet.

Subjects

It was desirable to obtain subjects for the study who would be representative of that segment of the population which engages in physical work. Consequently, subjects who were physically fit and whose ages were representative of the ages of the majority of individuals within the working population were chosen. The study is not concerned with individuals who were not physically fit or who were relatively young or old in relation to the normal working population.

Twenty-two of the officers and enlisted men of the Georgia Institute of Technology Army Reserve Officers Training Corps command volunteered to serve as subjects for the investigation. In addition to the military personnel, five graduate students also volunteered their services. The volunteers were divided into the following five age groups: 21 to 25 years, 26 to 30 years, 31 to 35 years, 36 to 40 years, and 46 to 51 years. The age group of 41 to 45 years was omitted, as no individuals of that age were among the volunteers. Three subjects were selected from each age group with age as the selection criterion and preference being given to the military personnel as they were considered more representative of the physically active, yet nonathletic segment of the population than the graduate students.

Thirteen subjects were chosen from among the military personnel, and two subjects were chosen from among the graduate students who volunteered. One of the graduate students selected was in the 21 to 25 year old age group, and the other was in the 26 to 30 year old age group. None of the subjects had previous experience with bicycle ergometers. The subjects' personal data are given in Table 1; the data include the percentage scores the military personnel had received on their most recent physical fitness test. The military physical fitness test was administered during the period of the experiment and thus the scores were representative of their current fitness. The two graduate students, subjects number two and five, and three of the military personnel, subjects thirteen, fourteen and fifteen, did not take the test; thus scores are not available for them.

Table 1. Personal Data Concerning Subjects

Subject	Age	Weight (lbs)	Height (in.)	Wt. Ht. Ratio (lbs in.)	Fitness Score
1	21	135	68	1.98	81%
2	22	177	70	2.53	---
3	25	169	76	2.22	88%
4	28	183	72	2.56	72%
5	28	185	71	2.60	---
6	29	155	71	2.20	77%
7	32	142	70	2.04	76%
8	34	194	70	2.77	76%
9	34	196	72	2.71	28%
10	36	132	71	1.86	71%
11	36	180	72	2.51	69%
12	39	181	72	2.53	64%
13	46	182	68	2.68	---
14	47	232	73	3.18	---
15	51	154	68	2.28	---

Tasks

Hall and Schwartz (7) (8) have shown that when work of a constant load is performed at varying speeds the speed of work significantly affects the level of pulse pressure. They have also shown that pulse pressure demonstrates a quadratic relationship with time as work cycles made up of intermittent work and rest periods progress. The present experiment was designed to determine the effect of individual tasks on the pressure level. As Hall and Schwartz had previously studied the effects of speed on the pressure level, speed of work was held constant in the present experiment and task intensities and durations were varied. It was not known whether task intensity or duration would more significantly affect the pressure level, however, so an experimental design balanced with respect to the number of levels of intensity and duration was selected. The design selected includes three task intensities and three durations.

Ekey and Hall (24) (7) have stated that energy outputs of .023 to .046 horsepower per minute maintained for three minutes by untrained subjects constitute mild exercise; whereas outputs of .064 horsepower per minute maintained for three minutes are somewhat strenuous. Wilkie (46) stated that in steady state work of five minutes or more duration that the upper limit of energy outputs for ordinary (nonathletic) individuals is .280 horsepower, and Muller (47) has shown that an individual's occupational working capacity is approximately twenty per cent of his maximum working capacity. Application of Muller's percentage to Wilkie's data reveals that the occupational working capacity for ordinary individuals performing tasks of five minutes or more in duration is .056 horsepower.

Experimentation by Karpovich and Prestrecov (48) with a group of subjects similar in age to those used in the present experiment indicated that individuals who had received no prior training on a bicycle ergometer could work for approximately ten minutes at a load of .06 horsepower before becoming exhausted.

From the above information, the task durations were set at two, five and eight minutes, and the energy outputs were set at .03, .05, and .07 horsepower per minute. These levels result in a total of nine different intensity-duration combinations, the minimum being in the range of Ekey and Hall's mild level, the median being somewhat below Wilkie's occupational working capacity level, and the maximum being approximately equal to Karpovich's exhaustive level. The energy outputs thus are representative of what appears to be the range of working capacity for the subjects.

The energy outputs were varied by having the subject maintain a constant number of revolutions per minute for each of the nine tasks and varying the load on the ergometer brake. For the particular bicycle ergometer used in this investigation, brake loads of 1.92, 1.37, and 0.82 pounds and a tachometer reading of 20 rpm resulted in the desired energy outputs.

The subjects were required to rest seated in the swivel chair for ten minutes before performing each task.

Experimental Design

A factorial experimental design (49) capable of isolating the effects upon the pulse pressure level of the different subjects within the five age groups, the age of the subject, the intensity of the tasks, and the duration of the tasks was utilized. The experimental design is shown in Figure 2.

		.03 HP			.05 HP			.07 HP		
		2 min.	5 min.	8 min.	2 min.	5 min.	8 min.	2 min.	5 min.	8 min.
A_1	S_1									
	S_2									
	S_3									
A_2	S_4									
	S_5									
	S_6									
A_3	S_7									
	S_8									
	S_9									
A_4	S_{10}									
	S_{11}									
	S_{12}									
A_5	S_{13}									
	S_{14}									
	S_{15}									

Figure 2. Experimental Design

Concomitant Variables

Although the concomitant variables were generally uncontrollable an effort was made to keep them within normal limits, and they were observed and recorded for possible analysis. The environmental concomitants recorded were room temperature, relative humidity, and barometric pressure. Values for these variables were recorded at the beginning of each performance. Subject concomitants considered were weight, height, weight height ratio, and relative physical fitness; the data have been presented previously in Table 1. As there seems to be some controversy as to whether a dinural effect occurs in blood pressure (see page 11) the time of day during which any one subject performed was held constant although subjects performed from 8:00 A.M. until 4:00 P.M. during the day.

Procedure

Prior to the experiment a laboratory schedule consisting of an orientation period and three performance periods was arranged for each subject. The length of the orientation period was approximately fifteen minutes, and the performance periods lasted approximately an hour each. The schedule was arranged so that the laboratory visits occurred on four different days with the exception of subjects one, seven, and ten. These subjects found it necessary to have the orientation period and the first performance period on the same day; a minimum of one hour separated the two periods in these cases. An attempt was also made to schedule the four laboratory visits within the same week, and this was possible with all subjects except numbers six, ten, and fifteen. The personal duties of these subjects made it necessary for them to schedule the laboratory visits over a two week period.

During the orientation period the general nature of the experiment was explained, the subjects weight and height were determined, the subject's blood pressure was taken to familiarize him with the recording technique, a seat adjustment and pedal arc radius were determined such that when the pedal was at the top of its arc the subject experienced a 60 degree knee-angle, and the subject was allowed to pedal the bicycle ergometer for two minutes to become accustomed to its operation. The knee-angle was held constant between subjects as previous experimentation had shown that it significantly affected one's ability to perform tasks of a pedaling nature (50). The subject was told that he would be asked to perform three tasks during each of the three performance periods, and that he should not engage in any abnormal physical activity immediately prior to his performance periods. He was also told that a set of instructions would be played to him at the beginning of each performance period on a tape recorder. It was explained that the tape recorder was being used to present the instructions to insure that each subject received exactly the same information prior to each performance concerning the procedure to be followed (51).

Prior to the first performance period the sequence in which the subject was to perform his nine tasks was determined with the aid of a table of random numbers. The task sequence was determined in this manner in an effort to randomize the effect of practice upon the tasks. The bicycle seat height and the pedal arc radius were adjusted for each subject prior to each performance period.

An explanation of the procedure used with one subject will suffice since all subjects were treated similarly.

According to his schedule for performance periods, the subject arrived at the laboratory at the beginning of the hour, removed his shirt and rested quietly for ten minutes in the chair. While the subject was resting, the location of his pulse was marked with a black marking pencil to aid in stethoscope placement, and the taped instructions were played to him. The text of the instructions follows.

> "This recorded set of instructions is being used to insure that all subjects receive the same information concerning the procedure to be followed. If you have any questions, please ask them at the completion of the tape. I will record your questions so as to have a record of them. When the instructions have been completed, I will tape the pressure cuff to your upper left arm so that it will be in position to record your blood pressure. When the cuff is in place I shall read your resting blood pressure level. After your resting blood pressure has been recorded, mount the bicycle, and I shall fasten the pedal straps around your shoes. Begin pedaling when I say go and maintain a speed of 20 rpm until I say stop. When you have stopped, rest your left forearm on the top of the bicycle in the manner I showed you during the orientation period, and I shall loosen the pedal straps, and you should again rest in the chair for ten minutes. This procedure, with the exception of playing the instructions, will be repeated three times during each performance period. After you have performed three times the pressure cuff will be removed, you will be reminded of the time for your next performance period, and you will be free to go. Your pressure readings will be furnished to you after all subjects have completed their nine performances. Please ask any questions you have at this time."

After the instructions had been played the procedure described in them was followed. Before telling the subject to begin pedaling he was reminded that he was to maintain 20 rpm until told to stop. When he began to pedal the environmental concomitants were recorded, and the valve of the pressure cuff bulb was adjusted so the cuff could be inflated at the completion of the task. While the subject was performing, the experimenter sat at the writing table with his back to the subject and watched the stop watch. The experimenter did not face the subject as he did not want to distract him or tempt him to talk while he was performing. At the completion of the task the experimenter told the subject to stop and moved from the table to the bicycle where he read the subject's blood pressure. Figures 3 and 4 present photographs of the subject's position on the bicycle ergometer and the author obtaining a blood pressure measurement.

An exception to the above procedure occurred with subject fourteen as he requested that the pedal straps not be fastened around his shoes. He stated that he believed they hindered rather than helped him and consequently they were not used. No other subject stated that he was bothered by the straps.

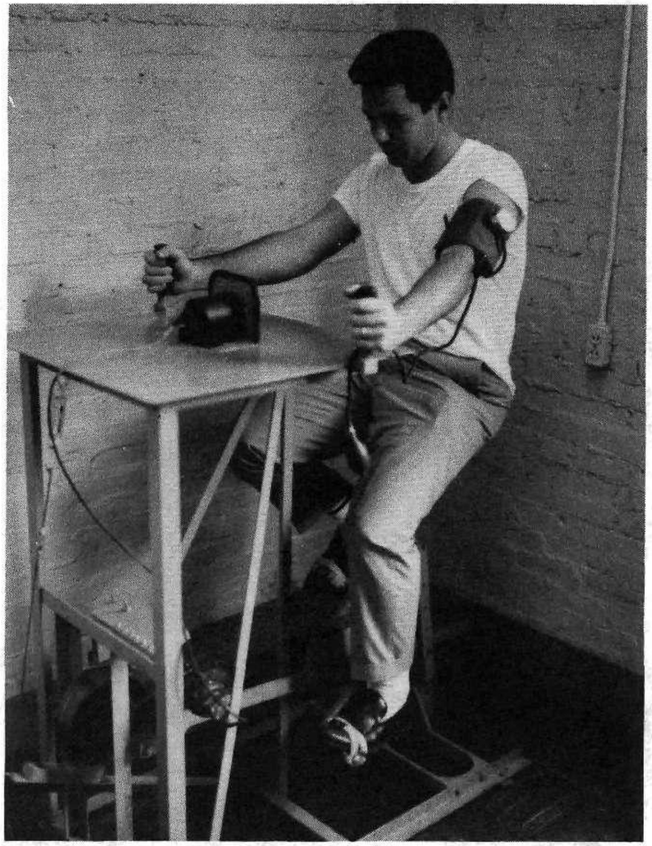

Figure 3. Subject Positioned on Bicycle Ergometer.

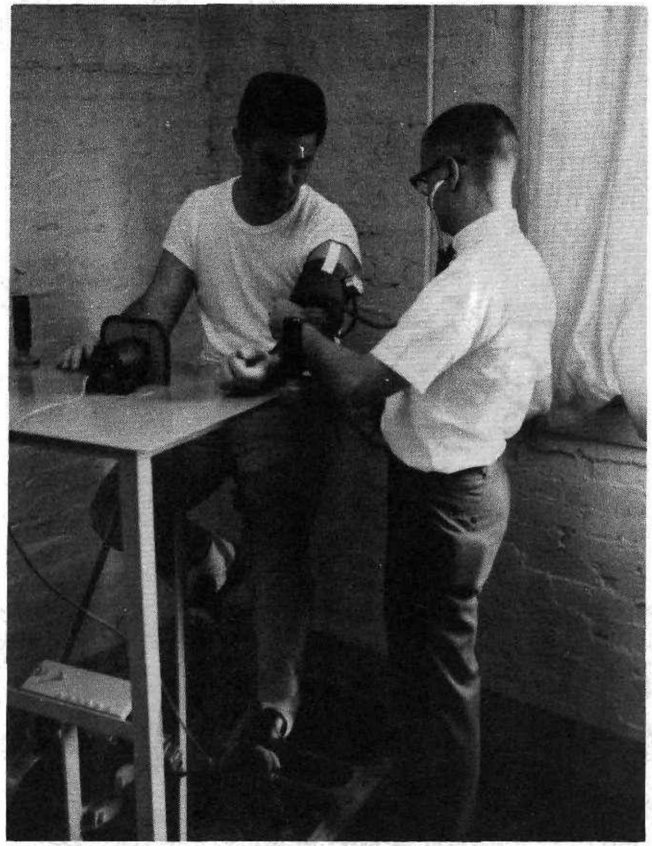

Figure 4. Measurement of Blood Pressure.

Photographs courtesy Mr. R. M. Thompson, Jr.

CHAPTER V

RESULTS AND ANALYSIS

The data resulting from the experiment and the manner in which they were analyzed are presented in this chapter.

Pulse Pressure Variables

The variable of principal interest in the investigation was the level of pulse pressure immediately following the performance of a task. In addition to post-task pulse pressure level, the difference between post-task and pre-task pulse pressure levels and the percentage increase of the post-task level over the pre-task level were considered. In the following discussion the difference between post-task and pre-task pulse pressure levels shall be referred to as the "net change" in the pulse pressure, and the percentage increase of the post-task level over the pre-task level shall be referred to as the "per cent increase." The per cent increase was calculated by dividing the net change by the pre-task level and is thus the amount by which the pulse pressure increased in moving from the pre-task level to the post-task level expressed as a percentage of the pre-task level.

Tables 2, 3, and 4 present values for the post-task, net change, and per cent increase pulse pressure variables resulting from the experiment. In nine, or 6.5 per cent, of the total of 135 tasks, the post-task pulse pressure was lower than the pre-task pressure; consequently, Tables 3 and 4 contain negative values in these instances.

Table 2. Post-Task Pulse Pressure Values

		.03 HP			.05 HP			.07 HP		
		2 min.	5 min.	8 min.	2 min.	5 min.	8 min.	2 min.	5 min.	8 min.
A_1	S_1	62	74	64	84	72	74	82	86	94
	S_2	52	48	44	56	60	46	62	62	64
	S_3	60	80	76	66	74	78	70	74	90
A_2	S_4	42	42	40	36	44	46	42	48	50
	S_5	40	34	40	30	38	34	36	26	34
	S_6	38	54	34	62	54	54	36	54	62
A_3	S_7	66	52	44	40	48	48	48	48	48
	S_8	34	48	58	38	40	50	36	42	42
	S_9	58	76	70	64	80	74	54	82	80
A_4	S_{10}	52	60	56	58	68	62	56	82	60
	S_{11}	46	48	46	48	50	52	48	44	60
	S_{12}	40	48	46	38	52	52	52	52	64
A_5	S_{13}	74	66	56	46	58	64	76	76	62
	S_{14}	40	48	50	50	44	48	42	54	50
	S_{15}	60	66	64	70	68	72	64	76	76

Note: Pulse Pressure Values are in Millimeters of Mercury.

Table 3. Net Change in Pulse Pressure Values

		.03 HP			.05 HP			.07 HP		
		2 min.	5 min.	8 min.	2 min.	5 min.	8 min.	2 min.	5 min.	8 min.
A_1	S_1	18	24	14	34	24	26	40	32	40
	S_2	18	4	12	10	10	-2	10	32	28
	S_3	10	32	24	16	10	-18	16	10	40
A_2	S_4	-6	4	6	8	14	2	4	8	10
	S_5	10	4	16	-2	8	2	10	-4	6
	S_6	0	10	-2	16	10	-16	0	14	14
A_3	S_7	18	22	10	6	8	4	10	6	10
	S_8	4	14	24	-2	14	24	12	16	14
	S_9	12	38	38	20	28	30	14	44	36
A_4	S_{10}	14	20	24	10	38	10	6	46	30
	S_{11}	0	12	10	10	8	14	18	8	20
	S_{12}	8	10	14	-2	16	18	28	22	38
A_5	S_{13}	42	22	18	2	20	14	18	28	16
	S_{14}	-2	10	14	8	-2	12	10	16	2
	S_{15}	14	22	2	26	20	32	28	30	14

Note: Pulse Pressure Values are in Millimeters of Mercury.

Table 4. Per Cent Increase in Pulse Pressure Values

		.03 HP			.05 HP			.07 HP		
		2 min.	5 min.	8 min.	2 min.	5 min.	8 min.	2 min.	5 min.	8 min.
A_1	S_1	40.9	48.0	28.0	68.0	50.0	54.2	95.2	59.3	74.1
	S_2	52.9	9.1	37.5	21.7	20.0	-4.2	19.2	106.7	77.8
	S_3	20.0	66.7	46.2	32.0	15.6	30.0	29.6	15.6	80.0
A_2	S_4	-12.5	10.5	17.7	28.6	46.7	4.6	10.5	20.0	25.0
	S_5	33.3	13.3	66.7	-6.3	26.7	6.3	38.5	-13.3	21.3
	S_6	0.0	22.7	-5.6	34.8	22.7	42.1	0.0	35.0	29.2
A_3	S_7	37.5	73.3	29.4	17.7	20.0	9.1	26.3	14.3	26.3
	S_8	13.3	41.2	70.6	-5.0	53.9	92.3	50.0	61.5	50.0
	S_9	26.1	100.0	118.8	45.5	53.9	68.2	35.0	115.8	81.8
A_4	S_{10}	36.8	50.0	66.7	20.8	126.7	19.2	12.0	127.8	100.0
	S_{11}	0.0	33.3	27.8	26.3	19.1	36.8	60.0	22.2	50.0
	S_{12}	25.0	26.3	43.8	-5.0	44.4	52.9	116.7	73.3	146.2
A_5	S_{13}	131.3	50.0	47.4	4.6	52.6	28.0	31.0	58.3	34.8
	S_{14}	-4.8	26.3	38.9	19.1	-4.4	33.3	31.3	42.1	4.2
	S_{15}	30.4	50.0	3.2	59.1	41.7	80.0	77.8	65.2	22.6

The three pulse pressure variables were analyzed by the analysis of variance technique (49). The data were coded in an effort to reduce the magnitude of the numbers in the analysis by subtracting forty from each post-task value, ten from each net change value, and thirty per cent from each per cent increase value. The analysis revealed that significant sources of variation in the data resulted from differences between the three horsepower levels, the three time levels, and the different subjects in each age group for all three of the pulse pressure variables and from the interaction between age and horsepower for the post-task and per cent increase variables. Tables 5, 6, and 7 present the results of the analysis of variance for the three variables, and Table 8 presents the distribution of the variance among the significant sources. As can be seen from Table 8, the difference between subjects accounted for the greater portion of the variance for all three variables.

Figures 5 and 6 illustrate the effect of the different subjects on the three pulse pressure variables. Figure 7 illustrates the effect of the different time periods on the three variables, and Figure 8 illustrates the effect of the different horsepower levels on the three variables.

The significant range test (52) using a five per cent level of significance was used to determine which subjects were significantly different. The results of the test are presented in Table 9. The table shows that in all of the age groups at least two of the subjects were significantly different for at least one of the pulse pressure variables, and in age group four all of the subjects are different from one another for at least one of the variables. The table also shows that fourteen of

Table 5. Analysis of Variance Data

for Post-Task Pulse Pressure

Source	Sum of Squares	Degrees of Freedom	Mean Square	Estimated F Value	5% F Value	1% F Value
HP*	708.68148	2	354.34074	7.56916	3.07	4.79
Time*	823.52593	2	411.76297	8.79577	3.07	4.79
HP Time	233.71852	4	58.42963	1.26015	2.49	3.52
Age	9875.37778	4	2468.84444	2.32157	3.48	5.99
Age HP**	808.35556	8	101.04444	2.17923	2.07	2.75
Age Time	148.62222	8	18.57778	0.38160	3.00	4.97
Age HP Time	369.24444	16	23.07778	0.42892	2.11	2.93
Subject (Age)*	10634.37037	10	1063.43704	19.76512	1.97	2.60
HP Subject (Age)	1058.07407	20	52.90370	0.97782	1.95	2.61
Time Subject (Age)	1456.29630	20	72.81482	1.62721	1.84	2.38
Residual	1789.92593	40	44.74814			
Total	27906.19260	134				

*Significant at the 1% level.

**Significant at the 5% level.

Table 6. Analysis of Variance Data

for Net Change in Pulse Pressure

Source	Sum of Squares	Degrees of Freedom	Mean Square	Estimated F Value	5% F Value	1% F Value
HP*	798.04444	2	399.02222	5.30549	3.07	4.79
Time*	774.57777	2	387.28888	5.14948	3.07	4.79
HP Time	34.31112	4	8.57778	0.11055	5.66	13.6
Age	2944.71111	4	736.17777	1.70727	3.48	5.99
Age HP	876.62222	8	109.57777	1.45854	2.05	2.68
Age Time	677.86667	8	84.73333	1.13999	2.06	2.70
Age HP Time	940.80000	16	58.80000	.75936	2.09	2.90
Subject (Age)*	4312.00000	10	431.20000	5.56866	1.97	2.60
HP Subject (Age)	1635.55556	20	81.77777	1.07623	1.75	2.20
Time Subject (Age)	1711.11111	20	85.55555	1.20162	1.84	2.38
Residual	2848.00000	40	71.20000			
Total	17553.60000	134				

*Significant at the 1% level.

Table 7. Analysis of Variance Data for

Per Cent Increase in Pulse Pressure

Source	Sum of Squares	Degrees of Freedom	Mean Square	Estimated F Value	5% F Value	1% F Value
HP*	7557.32573	2	3778.66286	6.55956	3.07	4.79
Time*	5084.34707	2	2542.17354	4.41308	3.07	4.79
HP Time	28.03116	4	7.00779	0.01171	5.66	13.6
Age	17119.12721	4	4279.78180	2.17852	3.48	5.99
Age HP**	10145.17724	8	1268.14716	2.12085	2.05	2.68
Age Time	6371.23590	8	796.40448	1.30100	2.06	2.70
Age HP Time	1682.94365	16	105.18398	0.15544	2.09	2.90
Subject (Age)*	19645.28186	10	1964.52819	2.90333	1.99	2.60
HP Subject (Age)	17698.42258	20	884.92112	1.45733	1.75	2.20
Time Subject (Age)	15888.92925	20	794.44646	1.54678	1.84	2.38
Residual	20544.29631	40	513.60741			
Total	121765.11796	134				

*Significant at the 1% level.

**Significant at the 5% level.

Table 8. Distribution of Variance

Table 8-A. Post-Task Pulse Pressure

Source	Variance	% of Total
HP	6.83393	5.1
Time	8.10998	6.1
Age HP	6.02563	4.5
Subjects (Age)	112.95814	84.3
Total	133.92768	100.0

Table 8-B. Net Change in Pulse Pressure

Source	Variance	% of Total
HP	7.19584	13.4
Time	6.93510	12.9
Subjects (Age)	39.55453	73.7
Total	53.68547	100.0

Table 8-C. Per Cent Increase in Pulse Pressure

Source	Variance	% of Total
HP	71.16908	20.6
Time	43.69154	12.6
Age HP	76.89921	22.2
Subjects (Age)	154.27488	44.6
Total	346.03471	100.0

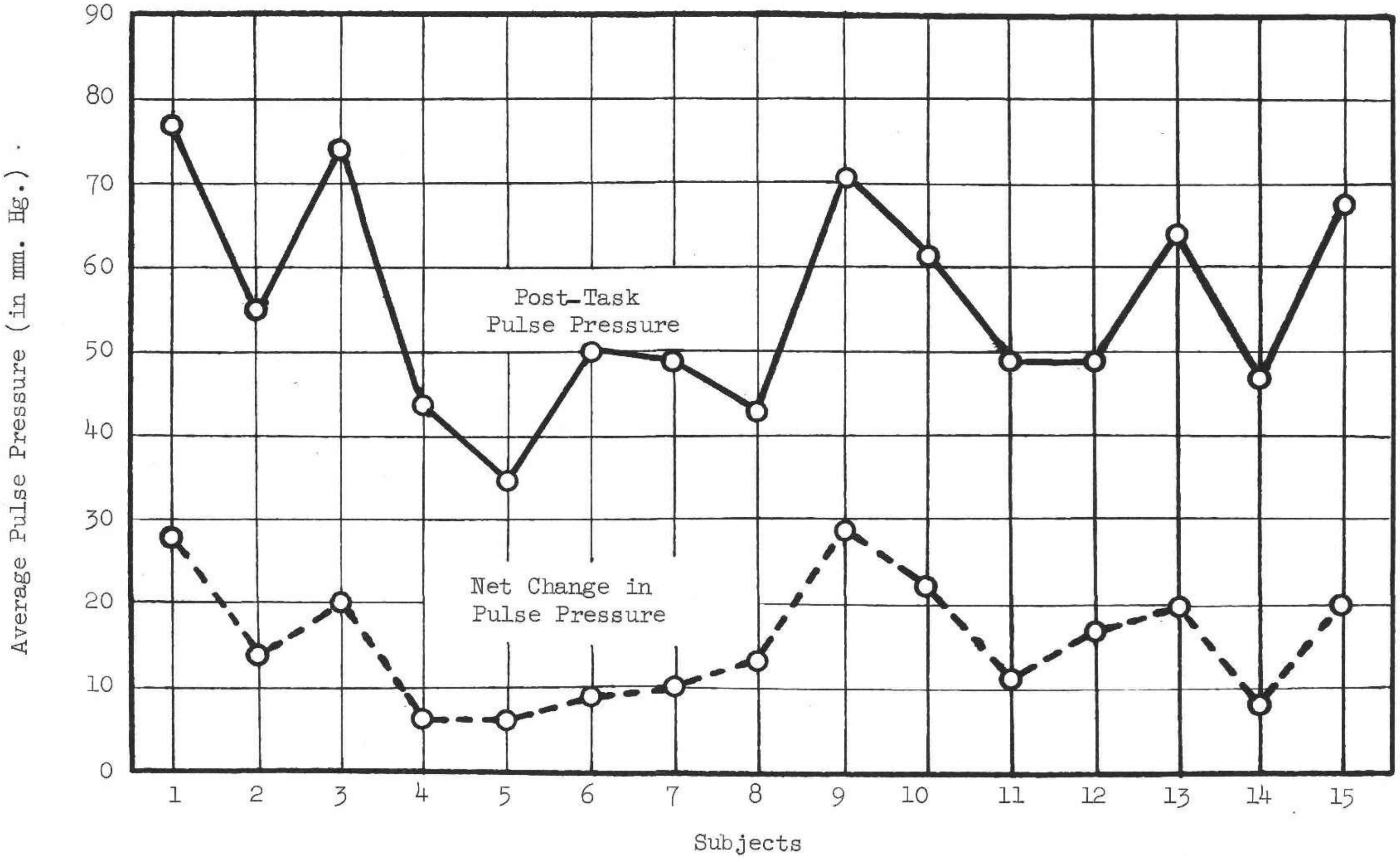

Figure 5. Average Pulse Pressure for All Tasks.

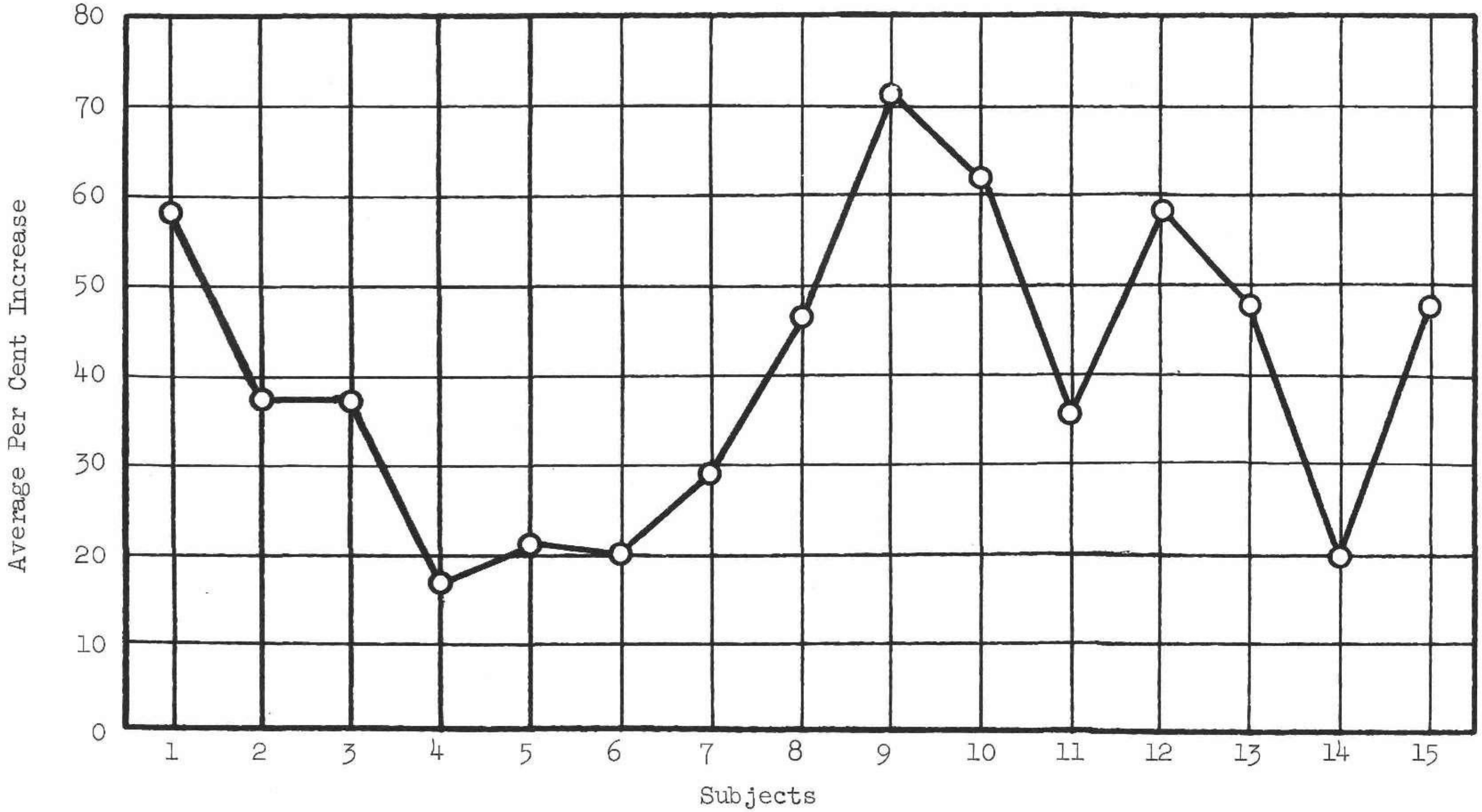

Figure 6. Average Per Cent Increase in Pulse Pressure for All Tasks.

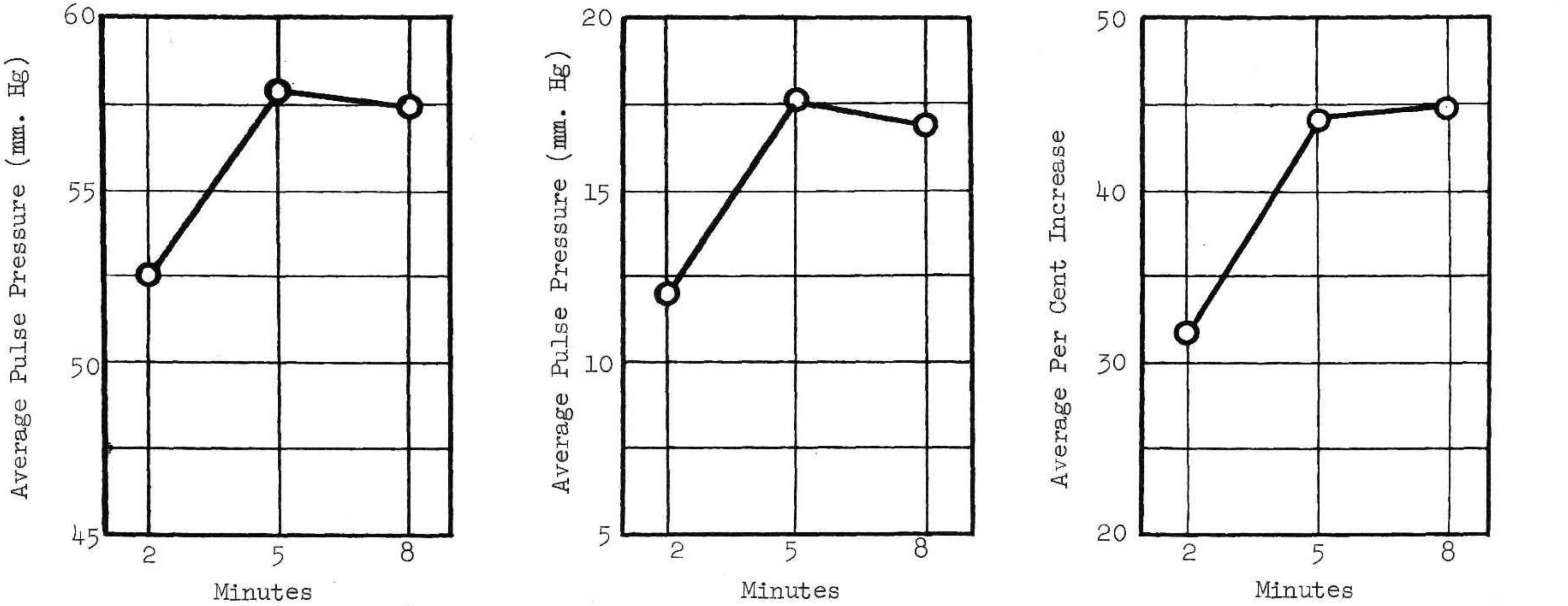

Figure 7-A. Post-Task Pulse Pressure

Figure 7-B. Net Change

Figure 7-C. Per Cent Increase

Figure 7. Average Pulse Pressure Variables for All Subjects and Horsepower Levels.

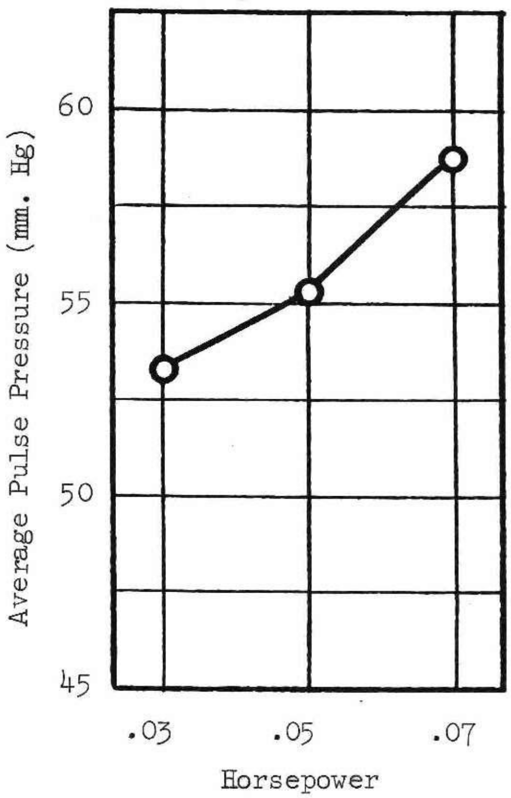

Figure 8-A. Post-Task Pulse Pressure

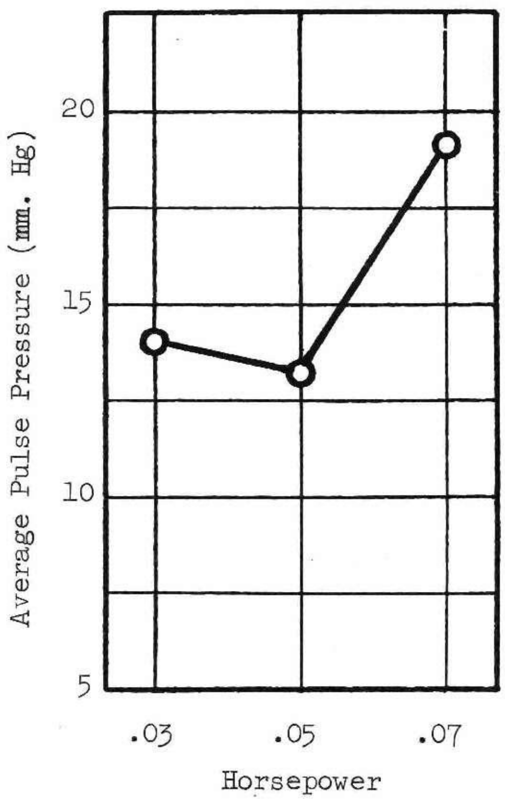

Figure 8-B. Net Change

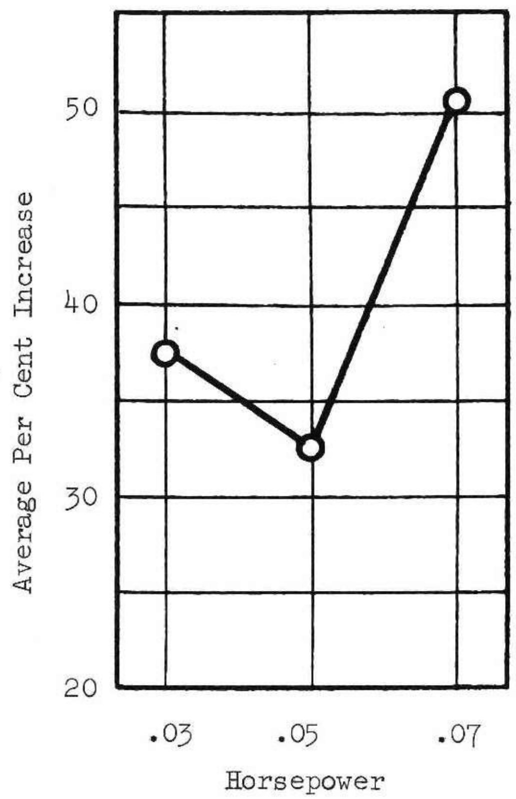

Figure 8-C. Per Cent Increase

Figure 8. Average Pulse Pressure Variables for All Subjects and Time Durations.

Table 9. Significantly Different Subjects

Subject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	--	AB													
2	AB	--	A												
3		A	--												
4	**	A	AB	--	A										
5	**	A	AB	A	--	A									
6	**		AB		A	--									
7	**		AB		A		--		**						
8	AB	A	A	C	A	C		--	AB						
9		**	BC	**	**	**	**	AB	--						
10	A		A	**	**	**	**	A	A	--	**	A			
11	**		AB		A				**	**	--	C			
12	AB		A	BC	**	C	C		AB	AB	C	--			
13	A		A	**	**	**	**	AB	A		A	A	--	**	
14	**	A	AB		A				**	**		BC	**	--	**
15	A	A		**	**	**	AB	A		A	AB	A		**	--

Table Interpretation: The cells indicate for which variables the two subjects are significantly different at the 5 per cent level. Subjects in the same age group are shown within heavy lines. Only one half of the table has been filled in for easier reading.

Legend: A = Post-Task Pulse Pressure
B = Net Change in Pulse Pressure
C = Per Cent Increase in Pulse Pressure
** = All Three of the Variables

the subjects are not significantly different from at least one subject of an age group other than their own, and that fewer of the subjects were significantly different from one another for the per cent increase variable than for the other two variables.

Application of the significant range test using a one per cent level of significance revealed that there was no significant difference between the five and eight minute time durations for all three of the variables and no significant difference between the two and five minute time durations for the per cent increase variable. The test also revealed that there was no significant difference between the .03 and .05 horsepower levels for the three variables and no significant difference between the .05 and .07 horsepower levels for the post-task pulse pressure variable.

Figure 9 illustrates the effect of the age-horsepower interaction on the post-task and per cent increase variables. Table 10 presents the age groups which were significantly different from one another for the different horsepower levels as determined by a five per cent significant range test.

Graphical analysis of the data revealed that the pulse pressure variables' levels were not indicative of the energy expended when the subjects were considered individually. The individual graphs are not presented, but the reader may refer to the rows in Tables 2, 3, and 4 if he wishes to compare the variables' levels at the different horsepower and time levels for each subject.

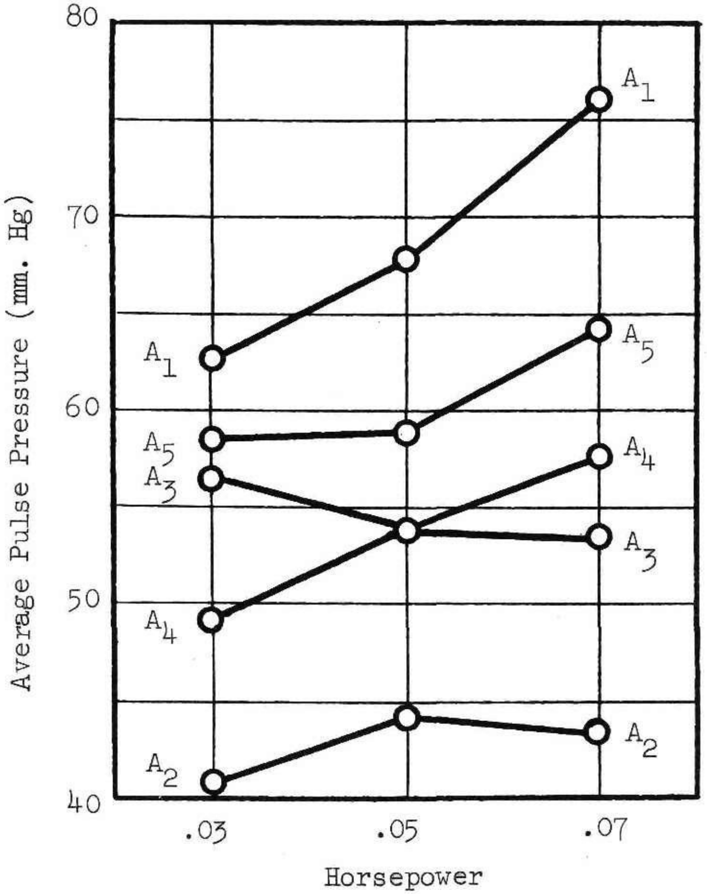

Figure 9-A. Post-Task Pulse Pressure

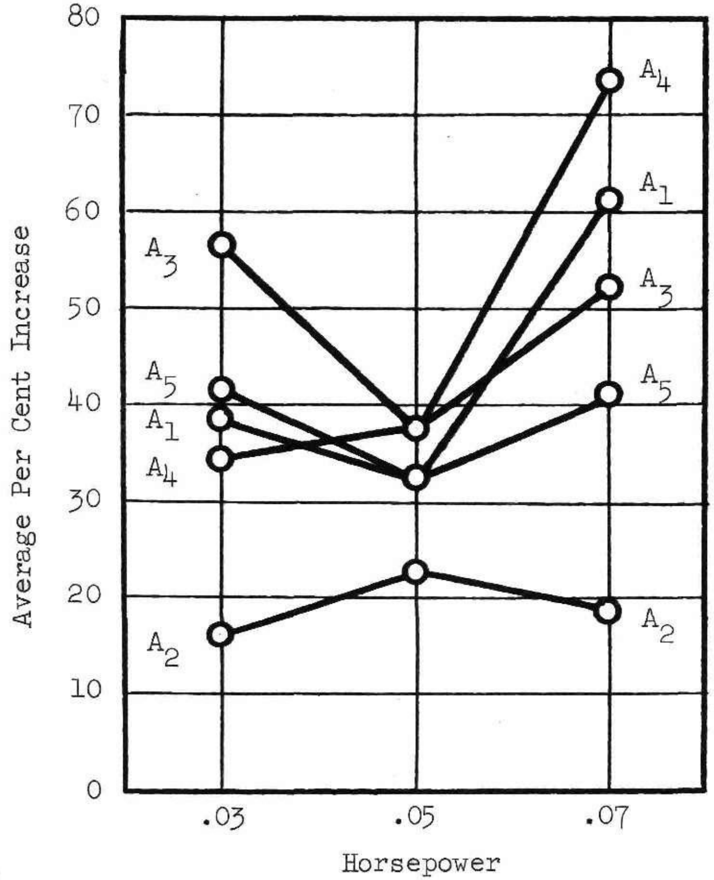

Figure 9-B. Per Cent Increase

Figure 9. Age-Horsepower Interaction.

Table 10. Significantly Different Age Groups

Table 10-A. Post-Task Pulse Pressure

	A_1	A_2	A_3	A_4
A_1	------------	------------	------------	------------
A_2	.03, .05, .07	------------	------------	------------
A_3	.03, .05, .07	.03, .05, .07	------------	------------
A_4	.03, .05	.03, .05, .07	.03	------------
A_5	.05, .07	.03, .05, .07	.07	.03

Table 10-B. Per Cent Increase in Pulse Pressure

	A_1	A_2	A_3	A_4
A_1	------------	------------	------------	------------
A_2	.07	------------	------------	------------
A_3	.03	.03 .07	------------	------------
A_4	------------	.07	.03	------------
A_5	------------	------------	------------	.07

Table Interpretation: Table cells show horsepower level for which the two age groups are significantly different at the 5% level.

Concomitant Variables

Environmental Concomitants

The environmental concomitants recorded in the experiment were temperature, relative humidity, and barometric pressure. During the experimental period the temperature during the task performances ranged from a low of 70 degrees Fahrenheit to a high of 86 degrees Fahrenheit, the relative humidity ranged from a low of 28 per cent to a high of 63 per cent, and the barometric pressure ranged from a low of 29.00 inches of mercury to a high of 29.35 inches of mercury. Table 11 presents the average value for these variables for each subject.

The environmental variables were arranged in increasing order and analyzed for a possible relationship with the pulse pressure variables by graphical and linear correlation techniques (53) in an effort to determine if the difference between subjects revealed by the analysis of variance was caused by a relationship between the environmental variables and the pulse pressure variables. The analysis revealed no relationship between the different environmental and pulse pressure variables.

Physical Fitness Concomitants

The physical fitness concomitants considered were weight, height, weight height ratio, and military physical fitness test score. Values for these variables have been presented previously in Table 1, Chapter IV. The physical fitness variables were analyzed in the same manner as the environmental variables with the result that no relationship was found between the physical fitness variables and the pulse pressure variables.

Table 11. Average Environmental Concomitants

Subject	Temperature In Degrees F.	Relative Humidity In %	Barometric Pressure Inches of Hg
1	78.0	47.9	29.23
2	83.3	50.7	29.10
3	83.9	47.0	29.27
4	78.1	58.6	29.26
5	73.2	37.2	29.14
6	79.1	50.3	29.24
7	73.9	39.8	29.24
8	80.7	48.0	29.24
9	82.6	47.9	29.27
10	80.8	50.2	29.17
11	79.8	57.9	29.22
12	79.8	50.0	29.28
13	71.7	41.6	29.19
14	71.8	43.6	29.18
15	81.1	47.8	29.26
Grand Average	78.5	47.9	29.22

Rest Periods

In an effort to determine if the rest periods were of sufficient length to allow complete recovery from the preceding task before the performance of a new task, the percentage of subjects whose resting pulse pressure ten minutes after the performance of a task was equal to, greater than, or less than the resting pulse pressure immediately prior to the task was computed. Table 12 presents the percentages and shows that the greater percentages were in the greater than and less than categories which indicates that the subjects, in general, were not in the same state at the beginning of each task performance.

Relationship of Subject Sample to Population

The average values of the resting pulse pressure levels of the subjects were compared with average pulse pressure levels as determined from larger samples of the male population (33) (34) to determine if the pulse pressure levels of the study subjects were generally representative of what could normally be expected for individuals of the same age. The comparison is presented in Table 13. Generally, the table indicates that the pressure levels obtained from the study subjects are lower than that which might normally be expected from individuals of the same age.

A possible explanation for the difference between the study data and that presented by Karpinos and Schnurman may be the conditions under which the pressure readings were made. The study subjects were familiarized with the technique of obtaining blood pressure measurements during their orientation periods and thus had no reason to be emotionally disturbed about the procedure followed. Conversely, the individuals in

Table 12. Change in Resting Pulse Pressure

Task				
Horsepower	Time in Minutes	Increase in Per Cent	Equal in Per Cent	Decrease in Per Cent
	2	36.4	0	63.6
.03	5	45.5	27.3	27.2
	8	41.7	33.3	25.0
	2	22.2	11.1	66.7
.05	5	0	14.3	85.7
	8	54.5	22.2	23.3
	2	40.0	10.0	50.0
.08	5	50.0	20.0	30.0
	8	20.0	0	80.0

Table Interpretation: The table shows the per cent of subjects whose resting pulse pressure 10 minutes after performance of a task was greater than, equal to, or less than the resting pulse pressure immediately prior to the task.

Table 13. Relationship of Subject Sample to Population

Age	Average Resting Pulse Pressure (Study)	Average Pulse Pressure (Schnurman)	Average Pulse Pressure (Karpinos)
21	48.9	53.0	
22	41.3	53.7	20-24 yrs.:49.3
25	54.2	51.7	
28	33.5	58.7	25-29 yrs.:49.7
29	41.2	58.1	
32	38.7	55.5	30-34 yrs.:49.7
34	35.9	52.6	
36	38.8	53.5	35-37 yrs.:49.7
39	32.4	51.6	
46	44.2	55.0	
47	39.8	53.9	
51	47.5	58.4	
55	----	59.2	
60	----	58.6	
65	----	63.9	

Note: Pressure readings are in mm. of mercury.

Schnurman's (34) sample includes 15,225 male employment applicants including those rejected as well as accepted.

Karpinos' (33) sample includes 273,000 white male military inductees including those rejected as well as accepted.

Karpinos' and Schnurman's samples were in the process of taking physical examinations and may not have been in a normal emotional state. If they were excited because of the nature of the examination their pressure level may have been somewhat elevated.

Another possible reason for the difference between the study data and those of Karpinos and Schnurman may be found in the nature of the samples. The study sample was composed entirely of physically fit individuals; whereas the samples of Karpinos and Schnurman included both physically fit and nonphysically fit individuals.

Based on the information presented by Karpinos and Schnurman, the pressure levels obtained from the study subjects may be somewhat lower than what is normally expected. Otherwise, the relation between the pulse pressure levels of the study subjects and their ages appears to be typical.

CHAPTER IV

CONCLUSIONS

The present experiment investigated the possibility of using the difference between the systolic and diastolic blood pressure levels as a measure of human energy expenditure. Analysis of the three pulse pressure variables, post-task pulse pressure, difference between post and pre-task pulse pressures, and per cent increase of post-task over pre-task pulse pressure indicated that their levels changed as the duration of the tasks changed. However, the change was not always significant. The analysis further revealed that the levels of the different variables were not homogeneous for the different subjects, that the lack of homogeneity could not be explained by differences in the environmental conditions in which the subjects performed or by differences in physical fitness as measured by a military physical fitness test, and that the variables were not indicative of the energy expended when the subjects were considered individually. Consequently, it is concluded that when tasks of a pedaling nature are performed by a human operator measurement of the differential between the systolic and diastolic blood pressure levels of the operator is not a reliable indicator of the energy expended in performing the tasks.

In previous investigations concerned with the measurement of post-task pulse pressure no significant variation was found among subjects (24). In the present investigation, however, 84.3 per cent of the total variance for the post-task pulse pressure variable resulted from the difference between subjects. The significant age-horsepower interaction in the present investigation may explain part of the reason for the conflicting results. In the earlier experimentation the subjects' average age was 20 years; whereas in the present investigation the subjects' average age is 33.9 years. Table 10-A of Chapter IV shows that the 21 to 25 year old and the 26 to 30 year old age groups were significantly different from all other age groups for almost all of the horsepower levels for the post-task pulse pressure variable. This indicates that there is a difference in the level of the post-task pulse pressure between young and older individuals, and this difference may have resulted in the significant difference found between subjects in the present investigation. It should be cautioned, however, that the lack of difference between subjects of different age groups and the difference existing between subjects within the same age group illustrated in Table 9 suggests that age may not be the only factor contributing to the subject difference. Consequently, no firm conclusion should be drawn concerning the effect of age without further investigation.

The results of the present investigation showed that differences in environmental conditions did not appear to effect the post-task pulse pressure variable significantly. This finding agrees with results of previous experimentation (7).

It should be noted that the rest periods of ten minutes used in the present investigation were perhaps not of sufficient length to allow complete recovery before the performance of each task and different results might have occurred if longer rest periods were utilized. It should also be noted that the present investigation concentrated its attention upon work performed by particular muscle groups, and different results might have occurred if more or different muscle groups were utilized in performing the tasks.

The following recommendations are made to those who may be interested in further investigating pulse pressure as a measure of energy expenditure. First, it is recommended that more levels of energy expenditure and task duration be considered including levels less than and greater than those considered in the present investigation. Second, it is recommended that several levels of task speed be considered so as to establish the relationship between pulse pressure and speed of work. Third, it is recommended that future investigations utilize several muscle groups to perform the tasks as the results of the present investigation are limited to tasks of a pedaling nature. Finally, it is recommended that longer rest periods be utilized between task performances so as to insure that the pre-task pressure level will be the same for all tasks.

A P P E N D I X

DATA SHEET

SUBJECT: ______________ AGE 36 WEIGHT 180 HEIGHT 5'11.75" WEIGHT HEIGHT RATIO 2.51

ORIENTATION PERIOD: DATE May 13 SYSTOLIC PRESSURE 128 DIASTOLIC PRESSURE 82

PERFORMANCE PERIODS:

DATE	H.P.	LENGTH	R.S.P.	R.D.P.	R.P.P.	HUM.	TEMP.	BAR. P.	W W.S.P.	W.D.P.	W.P.P.	CHANGE IN P.P.
5-14	.05	2	112	74	38	61	75	29.3	118	70	48	10
AT	.03	8	106	70	36	61	75	29.3	116	70	46	10
11:00	.07	5	114	78	36	61	75	29.3	116	72	44	8
5-15	.03	5	106	70	36	60	80	29.25	114	66	48	12
AT	.05	8	112	74	38	60	80	29.25	114	62	52	14
11:00	.07	8	110	70	40	59	80	29.25	120	60	60	20
5-17	.03	2	134	88	46	53	84	29.1	122	76	46	0
AT	.05	5	112	70	42	53	84	29.1	120	70	50	8
11:00	.07	2	116	86	30	53	85	29.1	116	68	48	18

COMMENTS: PEDAL ALL THE WAY DOWN, SEAT ON NO. THREE

Figure 10. Sample Data Sheet.

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